Reservoir Characterization of the Trenton Limestone, Illinois Basin

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Abstract

The Trenton Limestone is a widespread, shallow marine limestone of Ordovician age that occurs throughout the Illinois Basin in Illinois, Indiana, and Kentucky. Data from over 2600 wells were examined for this study, including wireline logs, core analyses, and sample and core descriptions. Several cores from across the basin were examined and an extensive search of literature was conducted.

Historically, production from the Trenton in the Illinois Basin has been limited to pronounced structures with significant closure. Many of these structures are associated with faulting. With one exception, Trenton fields occur above the -4500 subsea on the top of the Trenton. Thickness varies from less than 100 feet in southwestern Illinois to over 180 feet in southwestern Indiana. Four reservoir facies first identified by Crews (1985) can be tracked on wireline logs across the Illinois Basin. Reservoir rock is fossiliferous packestone and grainstone interbedded with impermeable cherty wackestones. Dolomite is common in surface exposures and the shallow subsurface, but relatively rare in deeper subsurface and productive fields. Porosity and permeability can vary but are low across the basin. The common presence of echinoderms and stylolites likely contributed to the loss of porosity and permeability. Diagenesis is extensive, evidenced by recrystallization, stylolites, pinpoint and vugular porosity, and fractures. Based on cores, the diagenetic history on the west flank of the basin may differ from the diagenetic history on the east flank of the basin. The best bbl/acre recovery occurs where maximum porosities exceed 8%. Historic oil production has occurred from 44 pools in 42 fields in Illinois and Indiana and totals over 25 MMBO.

Published data indicates that Trenton oil migrated post-Pennsylvanian in the Illinois Basin. However, a comparison of structural timing and oil fields indicates that no post-Mississippian structures have Trenton oil. The relationship between the timing of diagenesis, structural development and oil migration is poorly understood. A better understanding of this relationship may better constrain the development of Trenton reservoirs and identify where additional reservoirs can be found.

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RESERVOIR CHARACTERIZATION OF THE TRENTON LIMESTONE, ILLINOIS BASIN

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INTRODUCTION

- Data from over 2600 wells were collected and examined, including wireline logs, sample descriptions, core descriptions, well reports and scout tickets.
- Data from 44 oil pools in 42 fields were examined, with production to January 1, 2020.
- Core analyses from 51 wells across the Illinois Basin were collected and examined in Excel.
- Five cores were examined at state surveys in Illinois and Indiana.
- An extensive search of available literature was conducted.

Northern and Central ILLINOIS		Southern ILLINOIS		MISSOURI		SW INDIANA		Western KENTUCKY		Central KENTUCKY	
Group/Formation		Group/Formation		Group/Formation		Group/Formation		Group/Formation		Group/Formation	
					Girardeau LS				Drakes FM		Drakes FM
MAQUOKETA	Brainard SH Ft. Atkinson LS Scales SH	MAQUOKETA	Brainard SH Ft. Atkinson LS Scales SH	MAQUOKETA	Orchard Creek SH Thebes SS Cape La Croix SH	MAQUOKETA	Brainard SH Ft. Atkinson LS Scales SH	MAQUOKETA	Grant Lake LS Ashlock FM Calloway Creek LS Clays Ferry LS	MAQUOKETA	Grant Lake LS Ashlock FM Calloway Creek LS Clays Ferry LS
GALENA	Dubuque Wise Lake Dunleith Guttenberg Spechts Ferry	GALENA (Decorah)	Dunleith	KIMMSWICK LS		TRENTON LS		KIMMSWICK LS		LEXINGTON LS	
				DECORAH	Guttenberg LS Kings Lake LS Spechts Ferry FM						
PLATTEVILLE	Quimbys Mill Nauchusa Grand Detour Mifflin Pecatonica	PLATTEVILLE	Quimbys Mill Nauchusa Grand Detour Mifflin Pecatonica	PLATTIN	Macy LS Hager LS Beckett LS Bloomsdale LS	BLACK RIVER	Plattin FM Pecatonica FM	Plattin LS Pecatonica FM		HIGH BRIDGE	Tyrone LS Camp Nelson LS

Middle and Upper Ordovician, Illinois Basin

Area of study is bounded by:

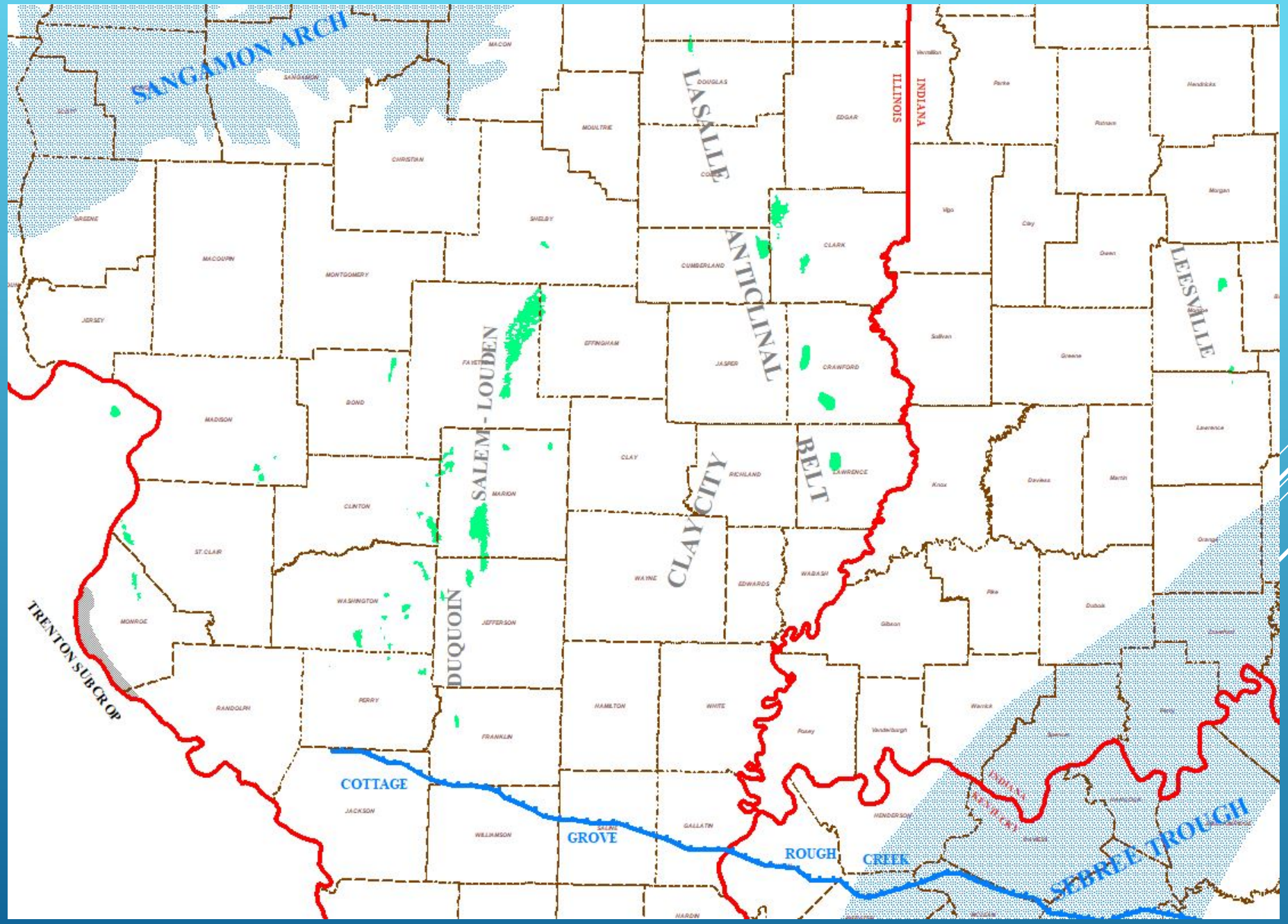
Rough Creek – Cottage Grove Fault system

Sangamon Arch

Sebree Trough

Eastern and western limits of Trenton production

GREEN – Trenton Fields



DEPOSITIONAL ENVIRONMENT

- Low angle carbonate ramp (below 1º) in a peritidal to subtidal environment that varied between lower and higher energies.
- Fossil content reflects a marine fauna that thrived near or below wave base.
- Basal Decorah has more shale than overlying carbonate sequence.
- The Trenton is bounded above and below by unconformities.
- Uplift and erosion also created an unconformity between the Decorah and overlying rocks.
- Deposition was interrupted on at least 13 occasions by volcanic ash, which left behind layers of bentonite and likely contributed the silica for chert formation.
- A patch reef was recently identified by Gabel and others (2016) in Jefferson Co., Missouri. **Stromatoporoids** (reef builders) identified in the patch reef have also been identified in core descriptions from Beaucoup Field (Washington Co IL) and a well in Marion Co IL.

STRUCTURE

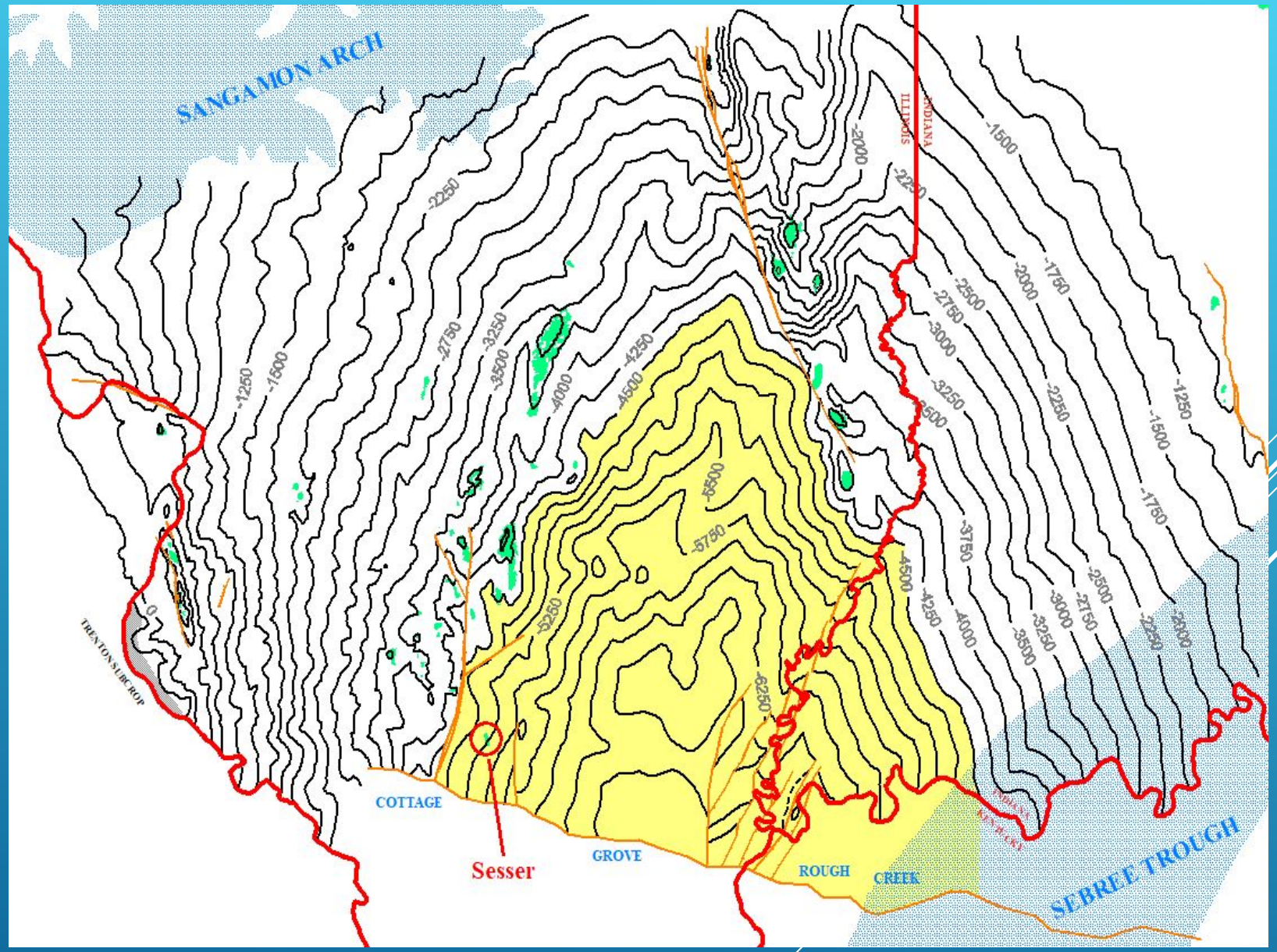
Oil fields located on a variety of anticlines and domes with significant closure (green).

Most Trenton fields are associated with faulting.

Five fields are associated with Precambrian hills.

With one exception, Trenton fields occur above -4500 subsea (yellow).

Exception: SESSER, Franklin Co. IL, is over 700 feet deeper than any other Trenton field in the Illinois Basin.



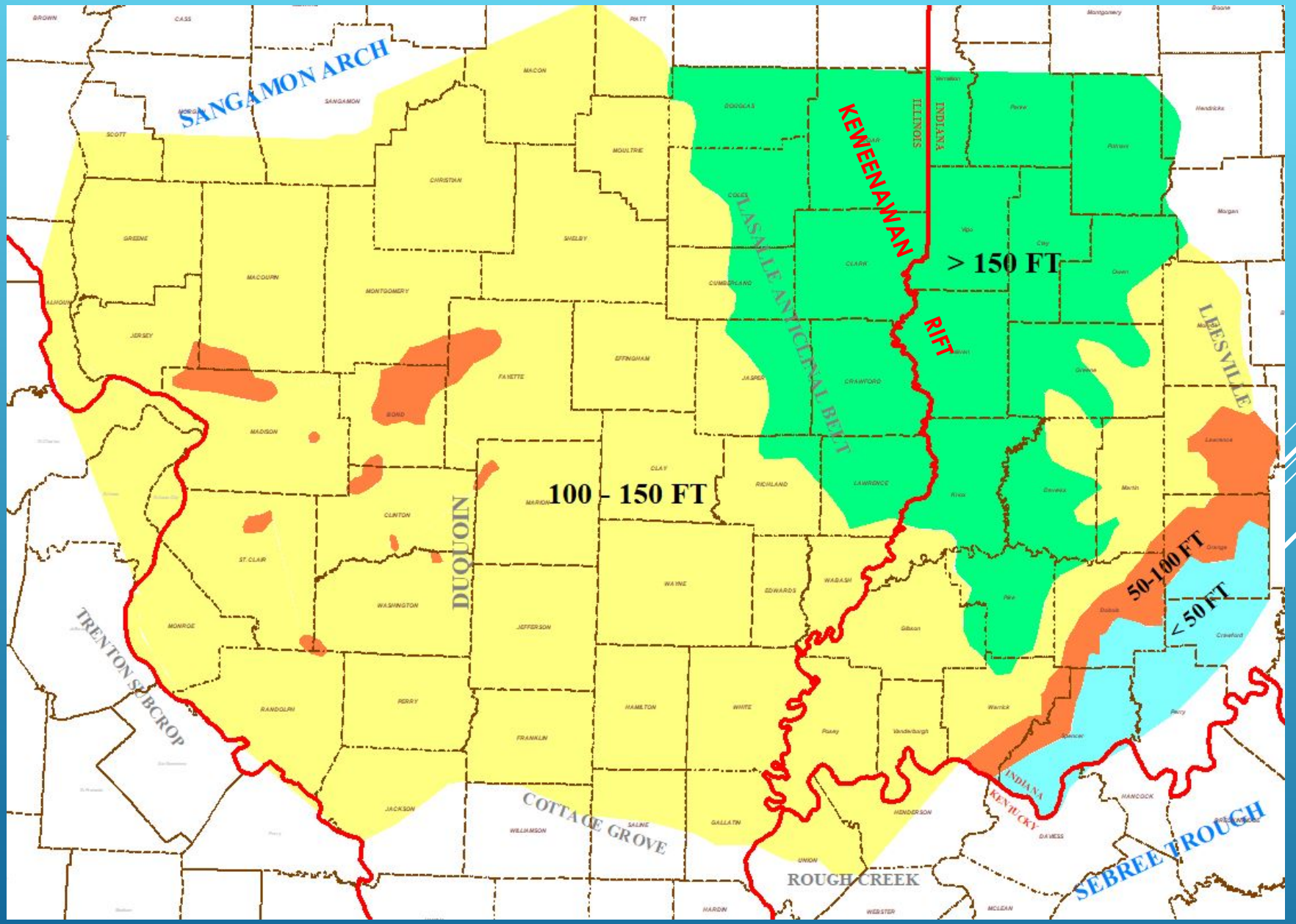
STRUCTURE – Top of Trenton, C.I. 250 FT

THICKNESS

Thins to **less than 100 feet** in SW Illinois, due to uplift of Ozark Dome during late Ordovician.

Thickens to **over 180 feet** east of the LaSalle Anticlinal Belt, correlating to a basement basalt rift.

Thins SE and grades laterally to shale in the Sebree Trough.



GEOLOGY

- **"Coarsely Crystalline" – Most common descriptive term: Reservoir packestones and grainstones**
- **"Fine Grained" – muddy wackestones that form cap rocks**
- **"Chert" – commonly part of the impermeable wackestone cap rocks. Crews (1985) correlated the cap rocks to chert zones in Missouri outcrops of the Trenton.**
- **"Dolomitic", "Sucrosic" and "Chalky" – vague terms used inconsistently in sample and core descriptions. Pe curves rarely record dolomite.**
- **"Pyrite" – usually reported at the top of the Trenton.**
- **"Fossiliferous" – Brachiopods and Echinoderms most common, followed by Bryozoans and Corals. Crews (1985) and Misra (1964) listed echinoderms as most common.**
- **"Stylolites" - 2nd most commonly mentioned feature after "coarsely crystalline".**
- **"Argillaceous" – reference to the presence of shale, most commonly swarms of paper-thin shale partings.**

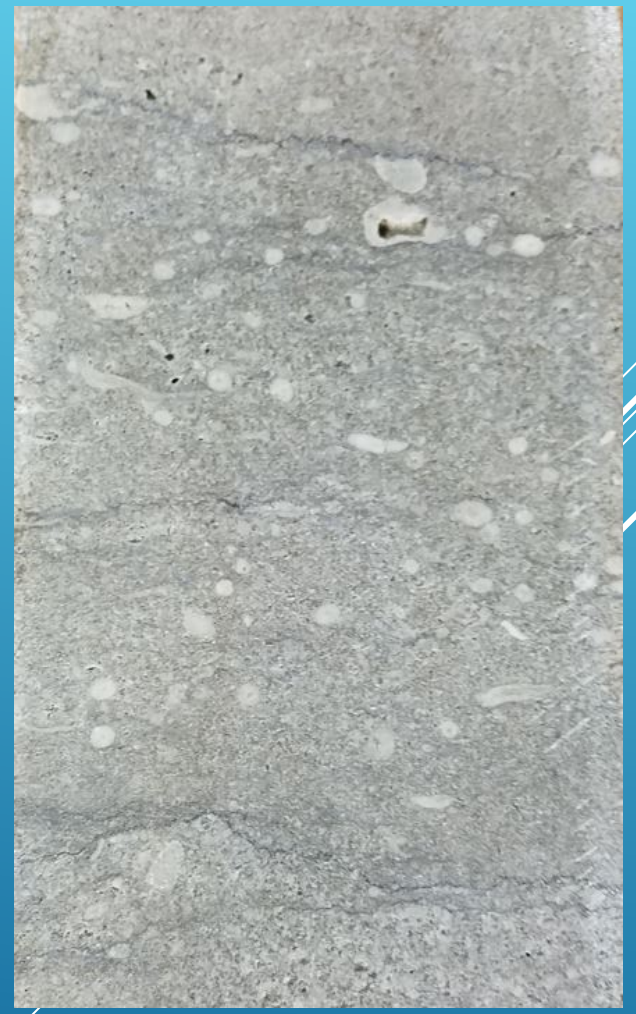
BED FORMS – based on Cores and Dip Meters

- Paper-thin shale partings common, often associated with Stylolites and chert zones (Cap Rocks).
- Both fining-upward and coarsening upward sequences identified in cores.
- Storm events – distorted bed forms with fossil debris and rip-up clasts.
- Disconformities evident in both core and dip meters.
- Based on limited dip meter data, bimodal cross bedding may be common with angles usually below 15 degrees.

POROSITY and PERMEABILITY

- Primary - Intergranular
- Secondary most common - Vugs, pinpoint porosity, and fractures.
- Echinoderms and Stylolites commonly associated with low porosity and permeability.
- Crews (1985) noted that porosity was associated with brachiopods and bryozoans in thin section and best where fossils were least abraded.
- Averages based on core analyses from 51 wells across the Illinois Basin:

Average:	5.1%, 2.5 md
Oil Fields:	6.3%, 3.85 md
Dry areas:	3.6%, 0.2 md



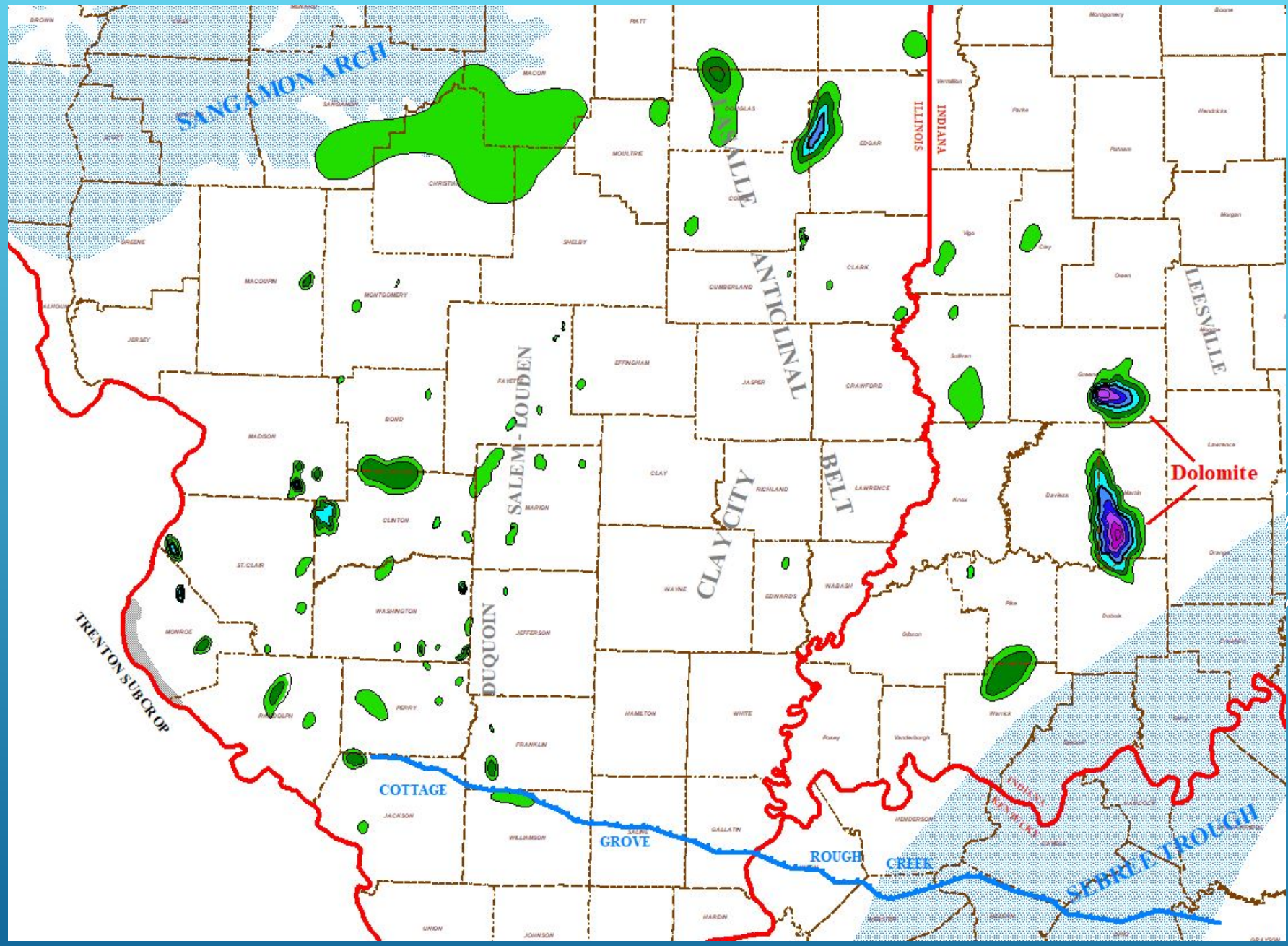
Trenton – Maximum Porosity

C.I. 3%, starting at 6%.

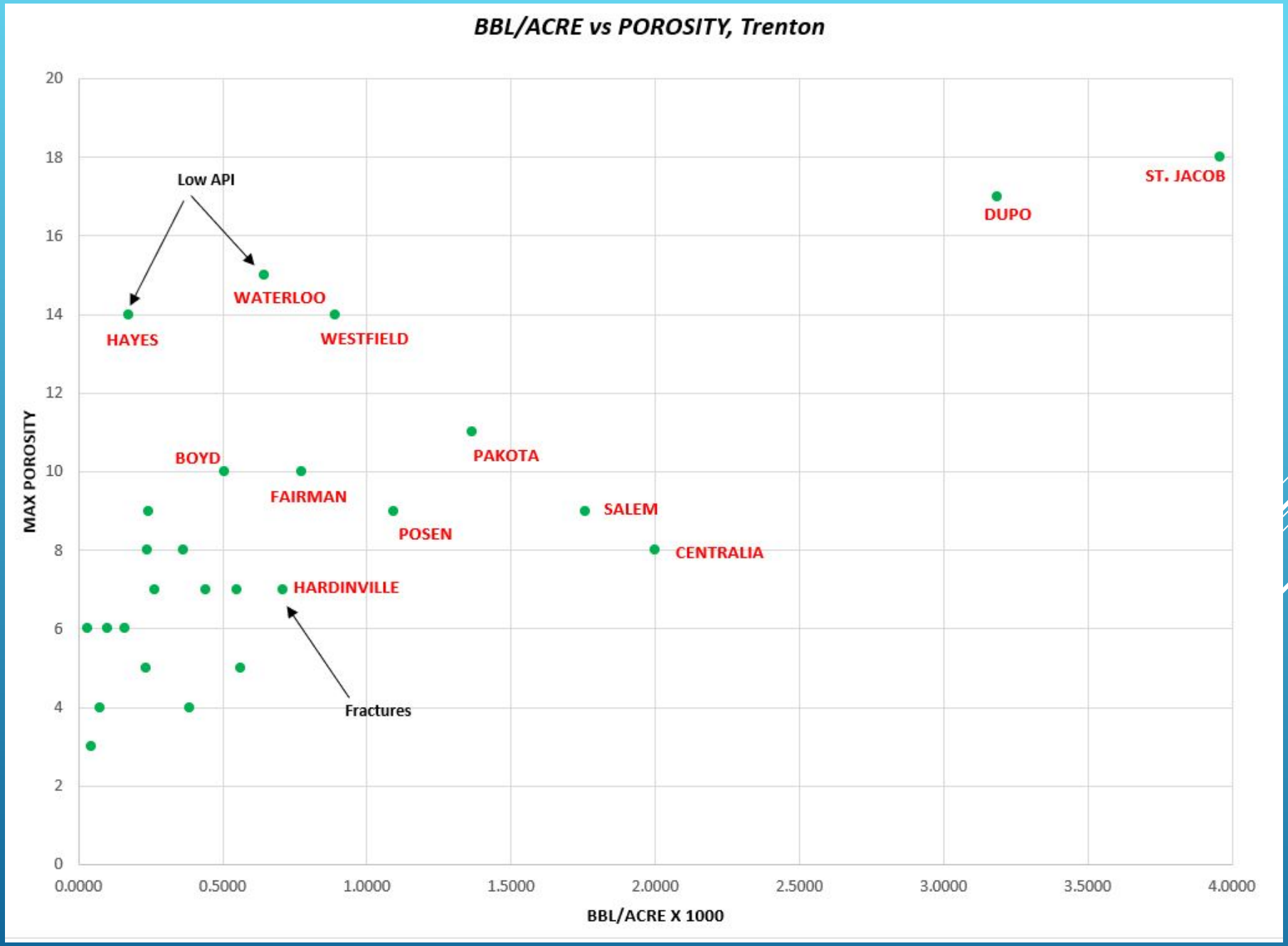
Maximum Porosity lowest in center of Illinois Basin, increasing toward edges of basin.

Dolomite trend in Indiana reaches 28%.

Based on both core and geophysical log data.



BBL/ACRE recovery INCREASES significantly where maximum porosity EXCEEDS 8%.



DIAGENESIS

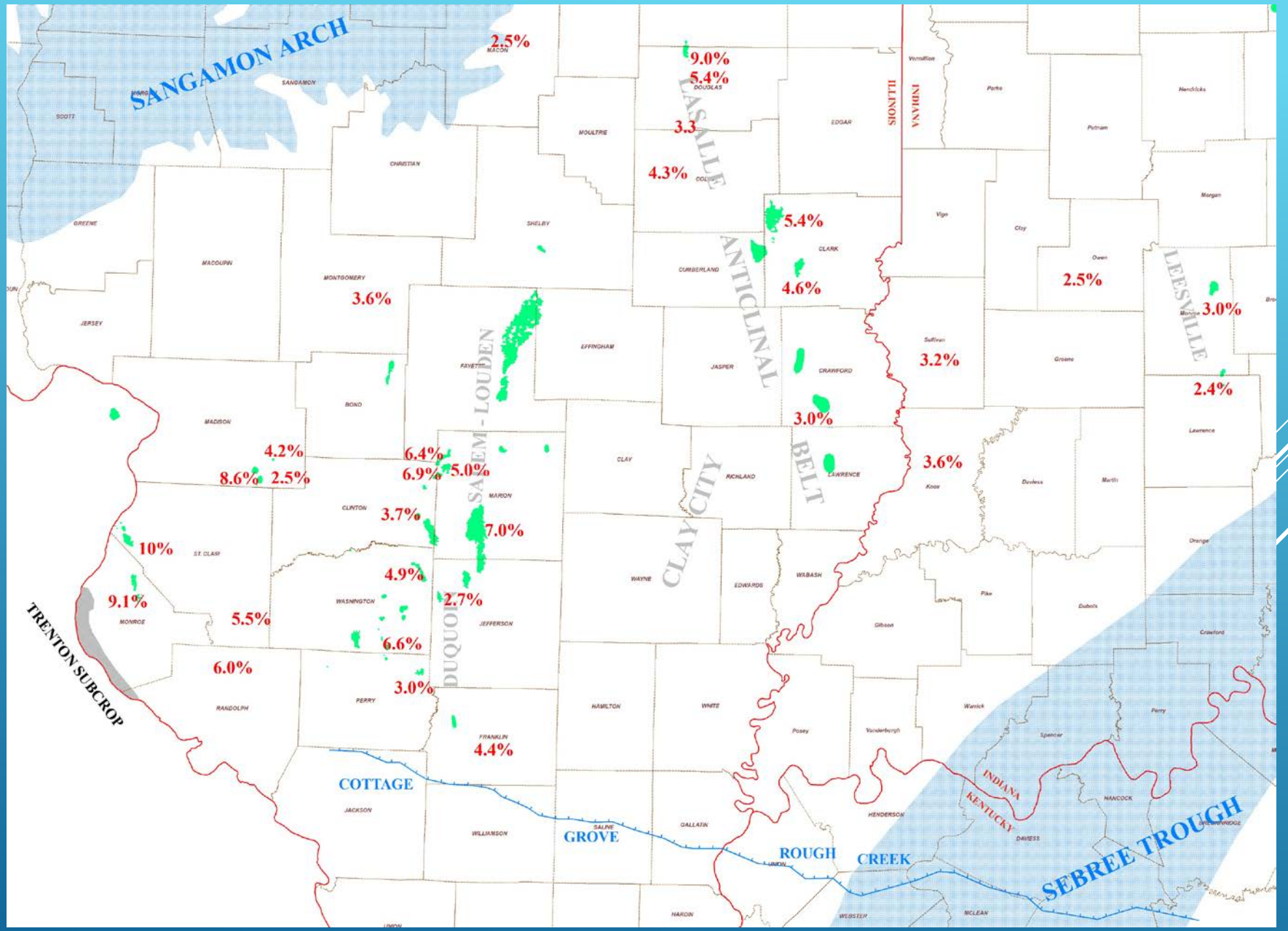
- **Basin Margins: Dominance of dolomite, Mississippi-Valley-Type (MVT) deposits, dolomitized reservoirs of Lima-Indiana Trend, higher porosities and permeabilities.**
- **Flanks and deeper: Extensive "recrystallization", stylolites, fractures often lined with calcite and/or dolomite, pinpoint and vugular porosity; low porosities and permeabilities.**
- **Evidence for widespread dolomite in the subsurface is lacking, but relatively more common at shallower depths.**
- **Crews (1985) studied the western side of the basin and found that dolomite rarely exceeded 10% of samples, and mostly occurred along "fissures" (fractures).**
- **Only significant dolomite trend located in Martin and Greene Counties, Indiana.**
- **Timing and history of diagenesis in the deeper Trenton of the Illinois Basin has not been resolved.**

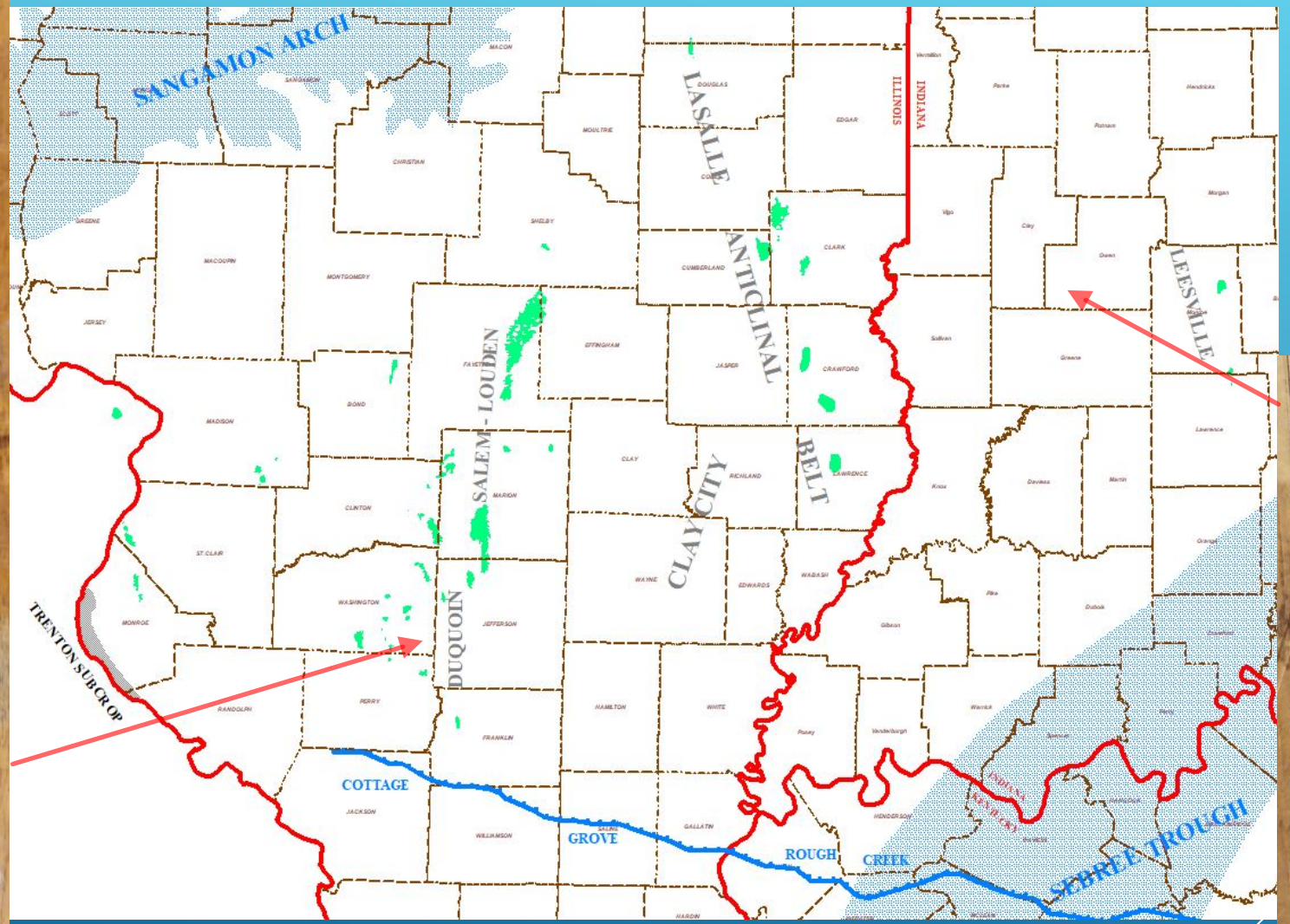
DIAGENETIC HISTORY MAY DIFFER ON EACH SIDE OF THE BASIN

Average Core Porosities are higher on the west flank of the basin compared to the east flank.

Guthrie and Pratt (1995) also suggested that the source of Trenton oil is different on each side of the basin.

Average core porosities increase up dip on the LaSalle Anticlinal Belt.

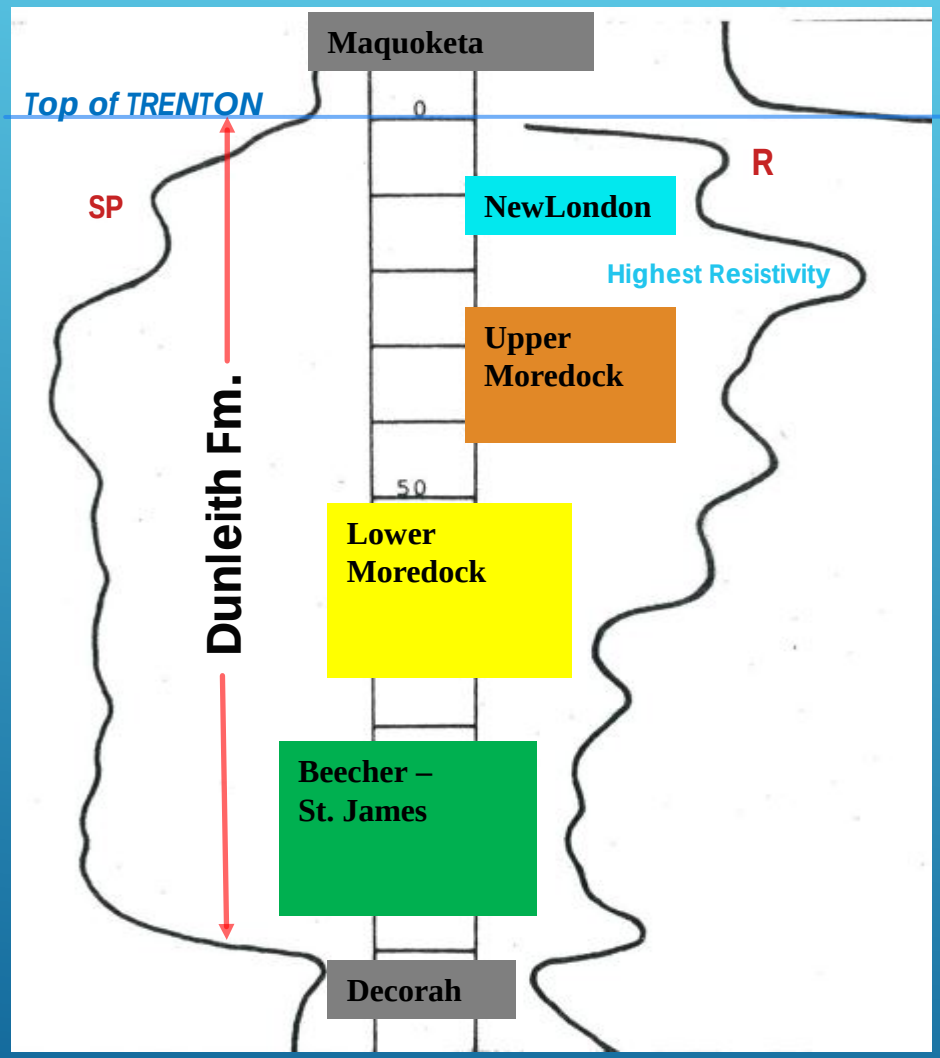




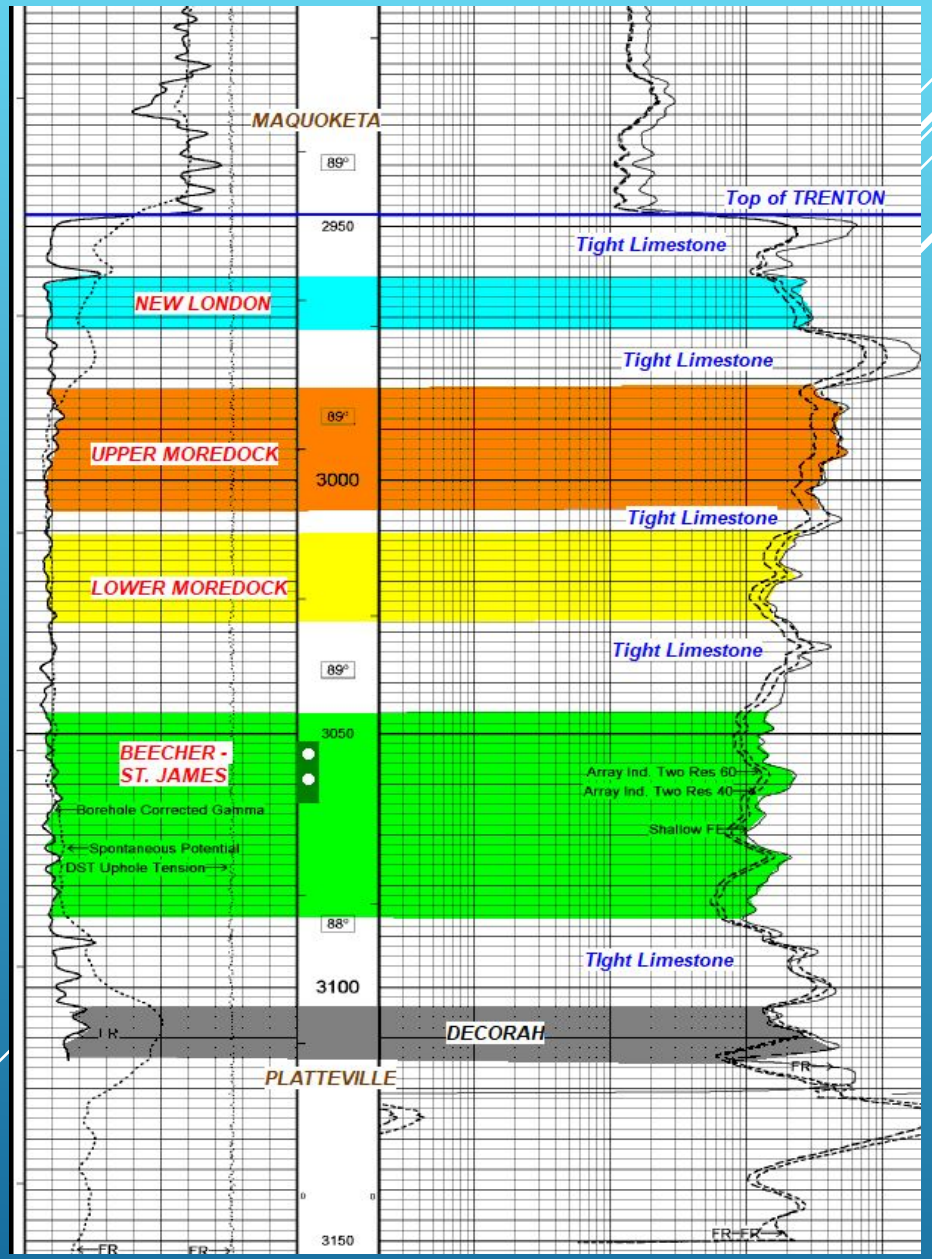
Lamczyk #4
Washington Co IL

Temple-Eastex #2
Owen Co., IN

FACIES PATTERN IDENTIFIED BY CREWS (1985)



Modified from Crews (1985)



Engelkes #T-3, Siggins Field, Cumberland Co IL

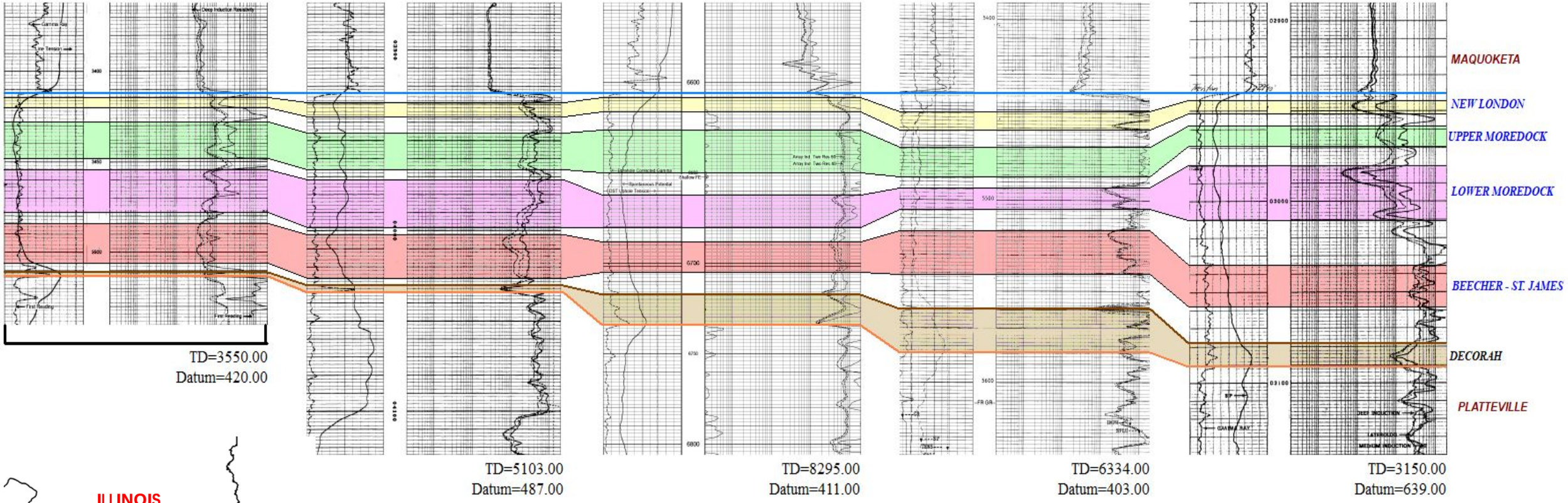
Sensmeyer 1
Santa Fe East
Washington Co., IL

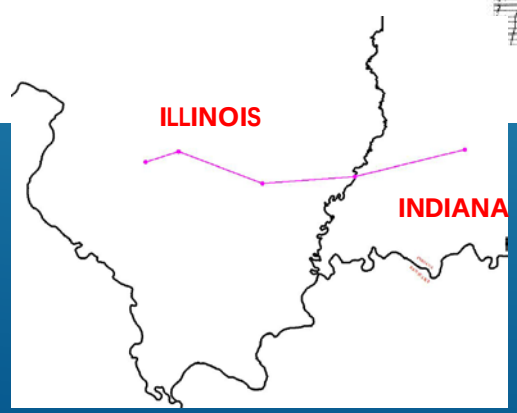
Copple 23-D
Centralia
Clinton Co., IL

Legg 1-010206
Wayne Co., IL

Carson 17
Wabash Co., IL

K.L. Sutton et al 1
Martin Co., IN





Facies pattern can be traced across the Illinois Basin.

DOMINANT PAYS – (44 pools in 42 Trenton Fields)

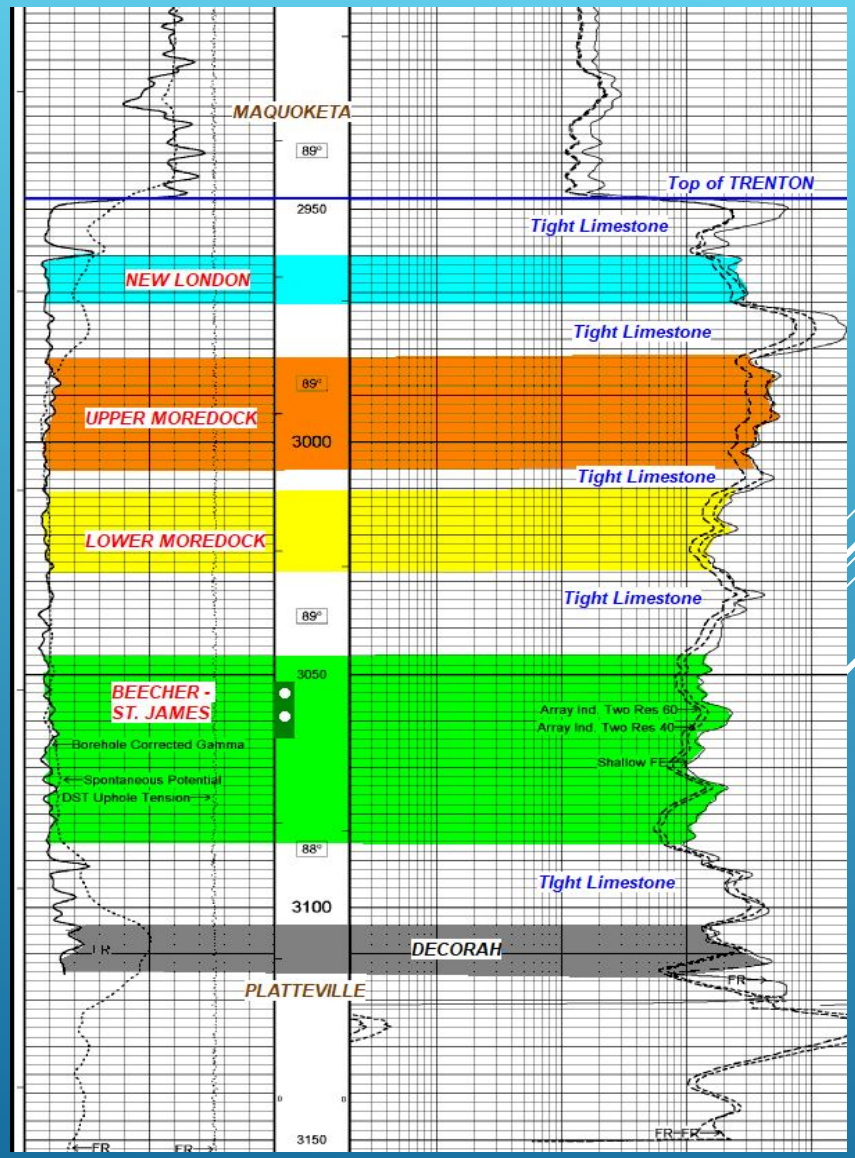
NEW LONDON – 21 of 44 Pools

UPPER MOREDOCK – 35 of 44 Pools; the high resistivity cap rock may trap leakage from deeper pays.

LOWER MOREDOCK – 9 of 44 Pools; primary facies of the Dolomite trend in Indiana

BEECHER-ST. JAMES – 17 of 44 Pools; greatest thickness and highest average porosity

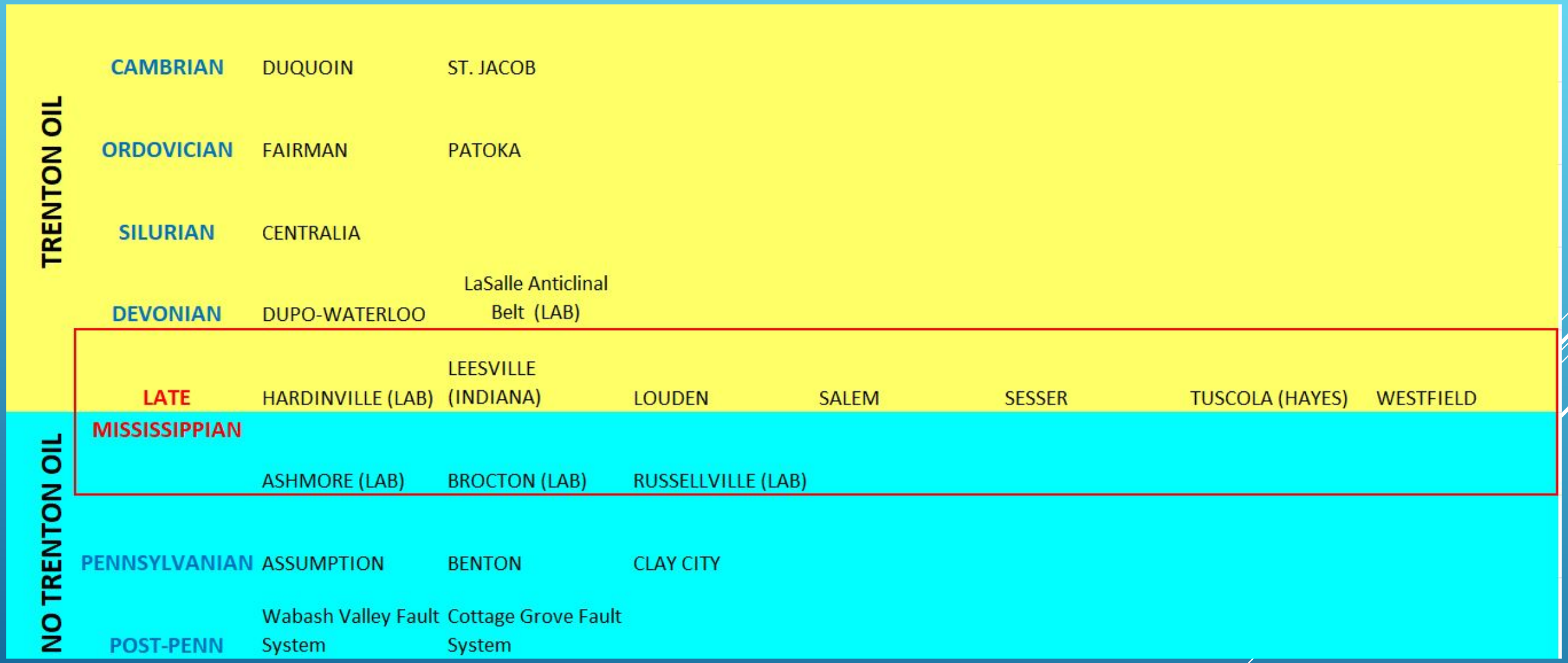
Many wells were completed "OPEN HOLE" in the Trenton, obscuring any determination of pay.



OIL PRODUCTION

- “Accurate” records are only available on 29 pools, due to lack of records and co-mingling with shallower pays.
- “Best estimate” for the Trenton in the Illinois Basin is 25.07 MMBO (1-1-2020) from approximately 20,000 acres.
- 75% of Trenton oil has come from just five fields (Centralia, Dupo, Salem, St. Jacob, Westfield).
- 25.07 MMBO = 0.56% of total production in Illinois Basin, similar to the 0.50% reported by Howard (AAPG Memoir 51, 1990).
- Average oil saturation in producing fields = 36.3%, six times the value for nonproductive areas.
- Average oil gravity = 37.8º, with a range of 28º (Louden) to 44.8º (Centralia)
- Largest recovery: St. Jacob, 3958 BBL/Acre
- 61% of Trenton fields are associated with production from Devonian carbonates.

ILLINOIS BASIN STRUCTURES and EARLIEST RECORD of DEVELOPMENT



SOURCES:
ISGS Bulletin 100
IGS Rept of Progress 16

LATE MISSISSIPPIAN – A turning point in the development of Trenton reservoirs

WHY?

1. What is the relationship between diagenesis and migration?
2. If migration occurred after the Pennsylvanian, why don't post-Mississippian structures have oil?
3. Low porosities and stylolites suggest oil migration occurred late in diagenesis or post-diagenesis.
4. Diagenetic history may be complex and vary from structure to structure.

CONCLUSIONS – “Absence of evidence is not evidence of absence.”

- Trenton reservoirs are found on the crest of anticlines or domes with significant closure. Small fields with less closure are still located along the trend of larger structures.
- Except for Sesser Field, all Trenton production is shallower than -4500 subsea on the top of the Trenton.
- Stratigraphic traps have not been found but cannot be ruled out. Could patch reefs play a role?
- Many Trenton fields are associated with faulting or close to major faults.
- Trenton fields are associated with structures that formed no later than Late Mississippian. There is no Trenton production on structures that formed post-Mississippian.
- The most productive fields have maximum porosities over 8%.

CONCLUSIONS (Continued)

- Four productive facies originally identified by Crews (1985) in the western part of the Illinois Basin can be tracked basin wide.
- Dolomite contributes relatively little to Trenton reservoirs and only increases toward the shallow edges of the basin.
- The diagenetic history of the Trenton may differ on each side of the basin.
- The history and timing of diagenesis in the Trenton has not been addressed in the deeper part of the Illinois Basin – When? And How?
- Faults may have been the main conduits for oil to reach low por/perm reservoirs on flanking structures with closure. Structures that lack Trenton oil may have lost too much por/perm, were too remote from the fault “pipeline” or developed after migration.

With only 2600+ well bores reaching the Trenton in the Illinois Basin, mostly on structures, there is still much we don't know about the Trenton.